RTO-50 Final Report

En route Controller Roles and Responsibilities in Support of En route Descent Advisor Inter-sector Planning

Prepared For:

NASA Ames Research Center
Moffett Field, CA 94035-1000

By:

Ken Leiden
Micro Analysis & Design, Inc.
4900 Pearl East Circle Suite 201E
Boulder, CO 80301

December 29, 2000

TITAN SYSTEMS CORPORATION
SRC DIVISION

1 Introduction

The goal of this project is to develop en route controller procedures that support the NASA Ames Research Center (Reference 1) trajectory orientation concept. These procedures will be utilized during controller-in-the-loop experiments to evaluate the En route Descent Advisor (EDA) decision support tool.

Trajectory orientation is an alternative to today's sector-oriented operations and requires a fundamental shift in thinking about inter-sector coordination. Today's sector-oriented operations are characterized by controller emphasis on actions to protect their sector's internal airspace. The primary focus is on the planning and tactical separation of aircraft within their sector. This planning also includes consideration for constraints, such as crossing restrictions, both within the sector and within close proximity to the sector boundary (to facilitate a handoff to the next sector). The handoff process is used to ensure that incoming flights are at least tactically separated. However, there is little visibility or control over the conformance of incoming flights with flow-rate restrictions. The sector closest to flow-restricted airspace not only has the greatest concentration of impacted flights, but also the greatest potential responsibility for conformance. Sector-oriented operations generally involve just enough cooperation between adjacent sectors to permit a handoff, but not enough to achieve an efficient flow of traffic.

Trajectory orientation, on the other hand, focuses on efficient flight planning that nominally conforms to all ATC constraints within a time horizon (e.g., 15-20 minutes) independent of airspace boundaries. In addition to separation, this approach emphasizes the upstream strategic planning of actions to conform to flow-rate restrictions in downstream sectors. The result is a distribution of workload away from the flow-impacted airspace. Instead of controllers operating relatively independently, with the main focus on protecting their sector's internal airspace, the controllers would work cooperatively across sectors and depend on each other for a well-planned flow of traffic.

Trajectory orientation will require new roles, responsibilities, and procedures for en route controllers that are quite different from today's operations. Rather than build a controller tool first and then determine the procedures to use it, the goal here is to determine procedures that best support trajectory orientation and ensure that those procedures are facilitated by the tool design. By defining the responsibilities and developing the procedures prior to EDA software development, the opportunity exists to define procedure-specific requirements to the EDA Build 3 system specification (Reference 2) that not only support trajectory-oriented planning, but actually promote and encourage it amongst en route controllers. Integration between the RTO-45 and RTO-50 teams has enabled these requirements to become part of a cohesive EDA Build 3 system specification.

2 EDA Requirements

This section lists EDA requirements necessary to support the trajectory-oriented Upstream Team approach that was described in detail in the RTO-34B Final Report (Reference 3). Most of these requirements are additions to the nominal EDA functionality represented by the CAST demo. Many of these requirements are necessary to support the multi-sector capability of trajectory orientation.

2.1 Conflict Types

Many of the assumptions about the implementation of the Upstream Team concept are dependent on the location of aircraft relative to the sector where the flow-rate conformance problem and/or conflict occur. Figure 1 depicts examples of different multi-sector conflict geometries. The naming convention for the different conflict types, Inter-sector, External, and External Intruder, and Intra-sector, comes from earlier research and is used here for consistency. The Intra-sector conflict type is not shown in the figure, but is simply a conflict involving a single sector (i.e., both aircraft and the location of the conflict reside in the same sector). Two examples are given for the External Intruder, External and Inter-sector conflicts to demonstrate variations that can result for conflicts detected over a twenty minute time horizon. Figure 1d (example 2 of the External Conflict) demonstrates that the conflict type can change as a function of the Time to Conflict. In this example, when Aircraft A transitions to Sector 3 and Aircraft B transitions to Sector 4, the conflict changes from External to Inter-sector. Likewise, example 2 of the Inter-sector Conflict demonstrates that the conflict type changes to External when both Aircraft A & B enter Sector 3.

Figure 2 depicts the relationship that Time to Conflict and Time to Sector Boundary can have on the controller's ability to strategically resolve a conflict. Case 1 depicts a nominal EDA situation in which either upstream controllers (Sectors 2 or 3) would have ample time to resolve the conflict before the aircraft enter Sector 1. Case 2 depicts a situation in which it would be highly advantageous for the either of the upstream controllers to resolve the conflict since the downstream controller would not have sufficient time to resolve it without requesting an early handoff. Case 3 depicts a situation in which neither upstream controllers has sufficient time to resolve the conflict prior to handoff. Since the downstream controller does have ample time to resolve it, the upstream controllers should handoff their aircraft without resolving the conflict. Case 4 demonstrates a rare situation in which all sectors (i.e., Sectors 1, 2, and 3) should be alerted of the conflict and coordination between sectors should be performed to ensure situational awareness is maintained and that the conflict is safely resolved.

Combining the examples depicted in Figure 1 with the cases depicted in Figure 2 results in dozens of possible scenarios that EDA must process correctly. In addition, either one or both of the aircraft may be constrained by flow-rate conformance restrictions, further increasing the number of scenarios. The EDA logic that determines which sectors should be notified of conflicts and/or flow-rate conformance problems must encompass all possible scenarios. The conflict notification logic is discussed next.

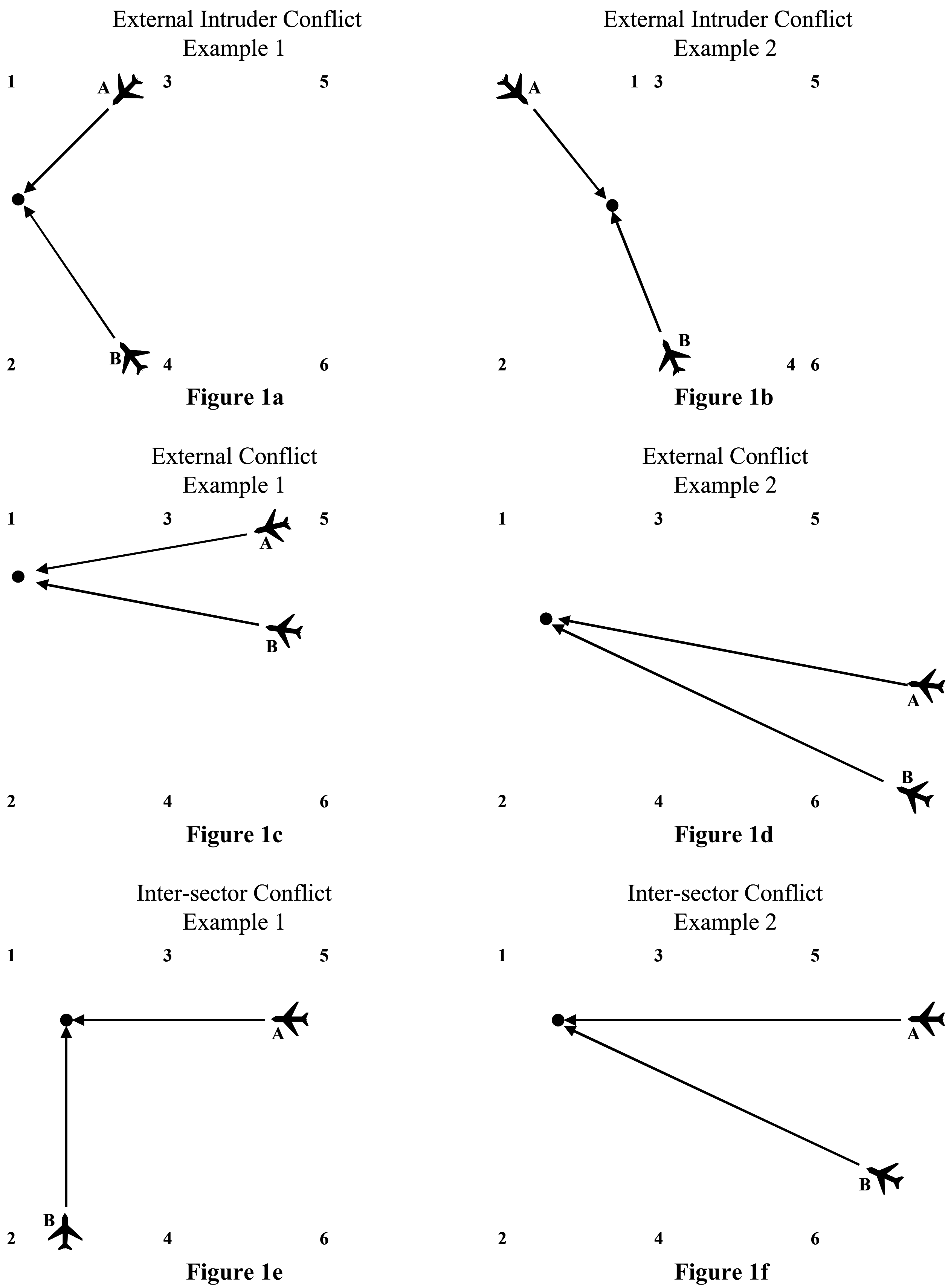

Figure 1. Examples of Aircraft Conflict Types

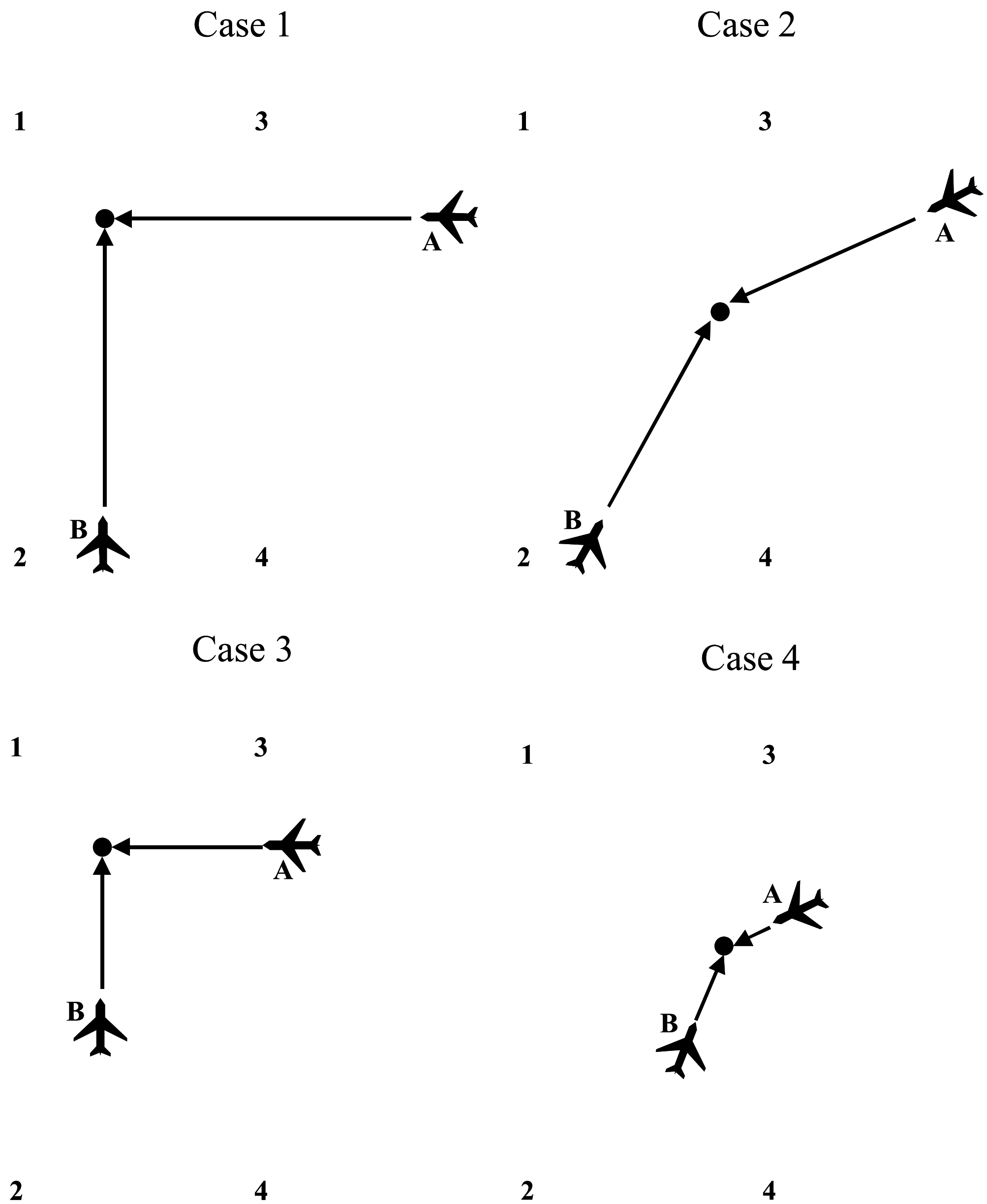

Figure 2. Relationship that Time to Conflict and Time to Sector Boundary Have on a Controller's Ability to Resolve a Multi-sector Conflict

2.2 Sector Notification of Conflict Detection

An important question to be answered by this research is what is the role of EDA for alerting sectors of conflicts that involve multiple sectors. A balance must be struck between notifying every sector of each conflict, thereby increasing coordination and workload, and not sufficiently notifying a sector that could have efficiently contributed to a strategic resolution. The conditions that result in notification of an EDA conflict alert to individual sectors are listed below:

EDA Sector Notification Requirement for Conflict Detection

1. When the Time to Conflict is less than 3 minutes, EDA alerts all sectors involved in the conflict. This includes the sector(s) where the conflicting aircraft currently reside and the sector where the conflict is predicted to occur. It also includes alerting any sector(s) that may be crossed by the conflicting aircraft from the current time to the time of the conflict (for a 3 minute time horizon, this is an unlikely event, but may occur when an aircraft crosses a corner of a sector's airspace (e.g., a conflict that involves a "point out" aircraft)).

2. When the Time to Conflict is greater than 3 minutes and the Time to the Sector Boundary for both aircraft is greater than 3 minutes, EDA alerts only the sector(s) that currently own the two aircraft. The sector where the conflict occurs is only notified if one of the aircraft in the conflict pair reside in that sector (e.g., External Intruder).

3. When the Time to Conflict is greater than 3 minutes and the Time to Sector Boundary for one of the aircraft (call this Aircraft A) is less than 3 minutes, EDA alerts the sector(s) that currently own the aircraft in the conflict pair. In addition, EDA alerts the sector(s) downstream of Aircraft A that would be penetrated over the next three minutes. Since the upstream controller might not have sufficient time to resolve the conflict before the aircraft departs the sector, this allows the downstream controllers to be aware of the conflict.

These conditional tests are done repeatedly (e.g., at the same rate as the tracks are updated). As an example, for Rule #3, if the Time to Sector Boundary for the other aircraft (call this aircraft B) is less than 3 minutes at some short time in the future then the same alerting logic occurs for Aircraft B as Aircraft A (i.e., EDA alerts the sector(s) downstream of Aircraft B that would be penetrated over the next three minutes).

These conditional tests are independent of conflict type. However, for clarification purposes, Table 1 shows the application of these rules to the conflict types depicted in Figure 1.

Time Criteria	Sectors alerted by EDA for Conflict Types Depicted in Figure 1		
	External Intruder Fig 1a	External Fig 1d	Inter-sector Fig 1e
	External Intruder Fig 1b	External Fig 1e	Inter-sector Fig 1f
Time to Conflict < 3 min	1, 2	1, 3	1, 2, 3
	1, 2, 4	1, 2, 3, 4, 6 Unrealistic	1, 3, 4, 5, 6 Unrealistic
Time to Conflict > 3 min and TSBA* > 3 min and TSBB** > 3 min	1, 2	3	2, 3
	1, 4	6	5, 6
Time to Conflict > 3 min and TSBA < 3 min and TSBB > 3 min	NA	1, 3	1, 2, 3
	NA	3, 4, 6	3, 5, 6
Time to Conflict > 3 min and TSBA > 3 min and TSBB < 3 min	1, 2	1, 3	1, 2, 3
	1, 2, 4	4, 6	4, 5, 6
Time to Conflict > 3 min and TSBA < 3 min and TSBB < 3 min	NA	1, 3	1, 2, 3
	NA	3, 4, 6	3, 4, 5, 6

Table 1. Example of Sector Notification Criteria

* TSBA – Time to Sector Boundary for Aircraft A
** TSBB – Time to Sector Boundary for Aircraft B

2.2.1 Active Conflict Detection List

An aircraft's active plan trajectory is the trajectory that the automation, and to a certain extent the controller, expects the aircraft to follow. An "active" conflict is a conflict between the active plan trajectories of two aircraft. The active conflict detection list is displayed on the controller's display. The list provides the controller with important information pertaining to multi-sector conflicts. An example of how a conflict detection list could be displayed is shown in Table 2 using Figure 3 as an example. The information presented in the conflict detection list can be used by the controllers to maintain situational awareness in a trajectory-oriented paradigm. In addition, the list indicates which sector nominally has responsibility for a conflict that involves multiple sectors. In Table 2, this is done by using a red color-code for both the ID of the aircraft that should be maneuvered and the sector that owns it (based on criteria discussed in Section 3.X and 3.X).

Other information that is important is whether an aircraft is subject to metering or spacing constraints and, if so, whether or not it is in conformance with the flow-rate constraint. This is represented in Table 2 by the '+' and '*' symbols respectively that appear next to the aircraft ID. Finally, there is a need for an indicator that would denote which sector has assumed responsibility (i.e., positive action has been initiated) for a multi-sector conflict to minimize interphone communication. One way to do this would be to use a different font (e.g., bold, italic font in Table 2). A subset of the full conflict detection list (Table 2 represents the full list) could be displayed nominally to minimize the display real estate. The full list could be displayed based on some GUI action from the controller.

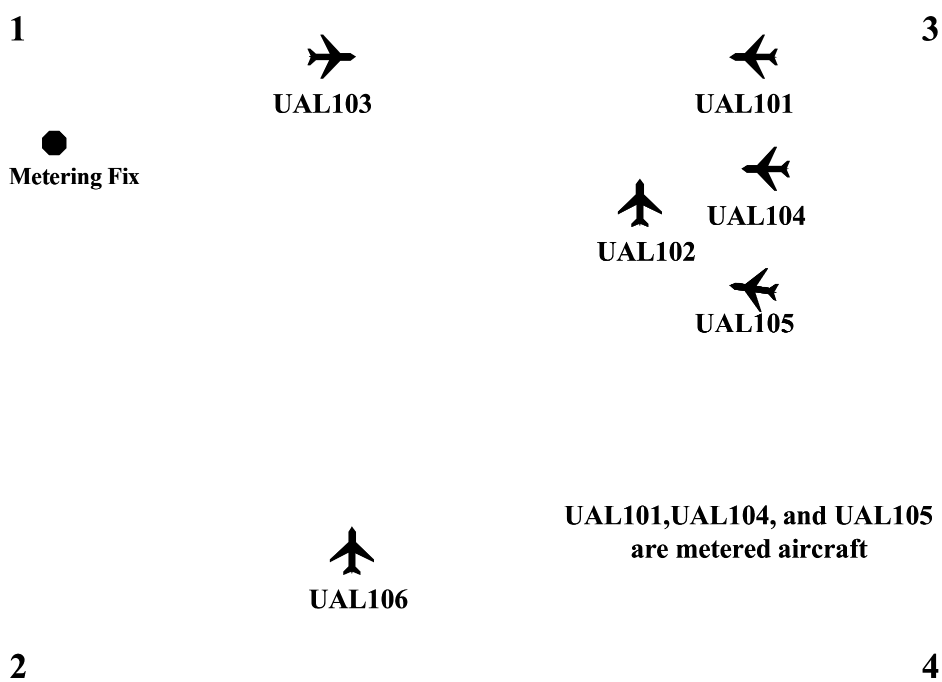

Figure 3. Representative Multi-sector Conflicts Involving Sector 3

Time to conflict	Conflict Type	Sector of conflict	ID of 1st Aircraft	Sector of 1st aircraft	Time to sector boundary	ID of 2nd Aircraft	Sector of 2nd aircraft	Time to sector boundary
3:20	Intra	3	UAL101+	3	6:50	UAL102	3	5:20
5:40	Ext Int	3	UAL101+	3	6:50	***UAL103***	***1***	***3:10***
9:40	Inter	1	UAL105*	3	7:10	UAL106	2	7:30
15:50	Ext	1	UAL105*	3	7:10	UAL104*	3	7:10

Table 2. Multi-sector Conflict Detection List for Sector 3 of Figure 3.

+ Indicates a metered aircraft that is in conformance with flow-rate constraints
* Indicates a metered aircraft that is not in conformance
The red-colored text indicates which aircraft in the conflict pair should be maneuvered
The bold, italic font indicates that a sector has taken positive action to resolve a multi-sector conflict

2.2.2 Provisional Trajectories and Conflicts

Provisional trajectories are trajectories being considered by the controller via the automation as potential active trajectories. A thorough description of provisional plans and trajectories is discussed in detail in the EDA Build 3 system specification. A summary, based on that document, is given below:

- Only one provisional plan trajectory exists for each aircraft for a given controller.
- Two or more controllers can have different provisional plan trajectories for the same aircraft.
- A provisional plan trajectory is, by default, visible only to the controller who created it. The creator of a provisional plan trajectory (not necessarily the owner of the aircraft) can "share" (i.e., make visible) a provisional plan trajectory with another controller.
- Accepting a provisional element modifies the active plan trajectory for that aircraft by adding the provisional element or replacing an existing active plan element with the provisional element.
- Only the sector that owns the aircraft can accept provisional elements and make them active.
- When aircraft are owned by different sectors, but are subject to the same flow-rate conformance restriction (i.e., aircraft bound for the same metering fix), the provisional trajectories for all those aircraft are shared amongst the respective sectors.

Provisional Conflict – A provisional conflict is detected in one of the following cases:

1. When both aircraft are owned by or shared with the same sector, only one of the aircraft has a provisional plan trajectory and that provisional plan trajectory has a potential conflict with the active plan trajectory of the other aircraft.
2. When both aircraft are owned by or shared with the same sector, both aircraft have a provisional plan trajectory and the two provisional plan trajectories have a potential conflict.
3. When the two aircraft are owned by different sectors, either one or both of the aircraft have unshared provisional plan trajectories and there is a potential conflict between the unshared provisional plan trajectory of one aircraft with the active plan trajectory of the other aircraft.

For provisional conflicts that involve more than one sector, a controller is not permitted to make a provisional plan "active" without prior coordination with the other sector.

In addition to the provisional conflict, there are two other types of indicators for predicting conflicts involving shared and unshared provisional trajectories.

Dependency Alert – When two aircraft are owned by the same sector or both are visible to that sector due to sharing and both have a provisional plan trajectory, there are four potential conflicts that can be identified. One is between the two aircraft's active plan trajectories, which is an active conflict. One is between the two aircraft's provisional plan trajectories, which is a provisional conflict. The other two exist between aircraft A's provisional plan trajectory and aircraft B's active plan trajectory and, similarly, between aircraft B's provisional plan trajectory and aircraft A's active plan trajectory. Potential conflicts between the provisional plan trajectory of an aircraft with the active plan trajectory of an aircraft with a visible provisional plan trajectory is called a dependency alert. Dependency alerts identify a dependency on the aircraft that has the provisional plan trajectory (in the identification of the conflict), not on the other aircraft.

Coordination Alert –Potential conflicts between the provisional plan trajectories of two aircraft that are not owned by the same sector and are not being shared are called coordination alerts. If there is a conflict between provisional plan trajectories of two aircraft, neither sector controller would be aware of this situation by looking at just active and provisional conflicts. The implication is that if one controller accepts their provisional trajectory, it would immediately appear as a provisional conflict for the other sector controller. This could impede the other controller's planning. A worse case is if both controllers accept their provisional plan trajectories at (approximately) the same time and immediately after an active conflict appears. Without the coordination alert, controllers might question why EDA did not predict the pending conflict. The display of a coordination alert to both sectors makes controllers aware of a potential conflict situation.

2.2.3 Provisional Conflict Detection List

In addition to the conflict detection list for active trajectories, a provisional conflict detection list is needed for provisional trajectories. Operationally, the difference between an active conflict and a provisional conflict is that an active conflict requires that one of the aircraft be diverted from its active flight plan to effect a resolution. On the other hand, a provisional conflict is an alert that signals to the controller that his/her potential plans for one or more aircraft will result in a conflict if they are executed. Unless the controller has a very specific plan in mind that consists of consecutive actions that are not made available to EDA, it would not be prudent to make the provisional plan active.

The information presented in the provisional conflict detection list would be similar to the active list. However, there are two pieces of information that would *not* apply to a provisional list. First, the indicator in the active conflict list that denotes which sector has initiated positive action (i.e., in the process of resolving) to resolve a multi-sector conflict is not needed in the provisional conflict list because it would not make sense. If a conflict appears in the provisional conflict list, it does not indicate that changes to the active plan are required to resolve it. Rather, it signifies that there is a problem with the provisional plan(s) and they should be adjusted until the provisional conflict disappears from the list. Second, the list would *not* need to indicate which sector nominally has responsibility for a conflict that involves multiple sectors. This is because the responsibility for purging the provisional conflict from the list lies with the sector(s) who owns the provisional plans.

2.3 Sector Notification of Metering Violations

Aircraft ID	STA	Delay (min)
UAL101	21:00	0
UAL104	22:00	1 (0)
UAL105	23:00	2 (1)

Table 3. Metering List

All sectors within a Center will display a metering list if metering is in effect. The list will have an entry for each metered aircraft in the sector. The entry will contain the scheduled time of arrival (STA), the required delay to meet the STA (negative delay would indicate the aircraft should be expedited) for the active trajectory, the remaining delay to meet the STA if the provisional trajectory were implemented, and the aircraft identification. A metered aircraft will be added to the list upon entering a sector and removed from the list upon exiting the sector. A sample metering list for Sector 3 in Figure 3 is shown in Table 3.

2.4 Sector Notification of Spacing Violations

In order to perform trajectory-oriented spacing, an approach is needed that develops a spacing plan for the entire Center analogous to way that TMA develops a plan for all arrivals. Described below are some ideas that would enable trajectory-oriented spacing. It is assumed that the spacing restriction must be met at the Center boundary.

- The reference used for determining trajectory-oriented spacing can be either a point (e.g., a fix) or a line (e.g., a sector boundary).
- The automation determines a sequence for all aircraft subject to the restriction within a Center (e.g., all aircraft within Cleveland Center bound for Newark, JFK, or LaGuardia).
- The sequence is based on the order that active plans reach the spacing reference.
- Any aircraft in a sequence that meets the spacing restriction is defined as a "reference aircraft". There can be more than one "reference aircraft" in a sequence. When a reference aircraft is encountered in the sequence, the spacing calculator is reset – the required spacing for subsequent aircraft (i.e., aircraft lower in the sequence) is based on this reference aircraft rather than a reference aircraft higher in the sequence.
- All aircraft subject to spacing restrictions can be shown in the spacing list or just the aircraft in the sector's jurisdiction. If the list displays all the aircraft, then the aircraft in the sector's jurisdiction are color-coded (e.g., the red font in Table 4).

An example of a spacing list that demonstrates the above ideas is shown in Table 4. Table 5 shows what the list would look like after the controller makes AAL329's provisional plan active. The provisional plan for AAL239 provides 5 nm more spacing than required by the 20 nm spacing restriction. Because of this, the 5 nm ripples through the system, requiring 5 nm of delay for subsequent aircraft until TWA734. Prior to this action, DAL891 was in conformance with the restriction and was considered a reference aircraft. After the action, AAL239 becomes a reference aircraft, but DAL891 is no longer a reference aircraft.

Aircraft ID	Current spacing (distance between this aircraft and aircraft ahead of it)	Required spacing for this aircraft	Spacing achieved if this aircraft's provisional plan is implemented
DAL721*	30	0	NP
UAL104	15	5	0
CAL155	15	10	NP
AAL329	5	25	-5
TWA463	5	40	0
CAL621	50	10	NP
DAL891*	30	0	NP
UAL333	10	10	NP
TWA734*	45	0	NP

Table 4. Spacing List for Center Airspace Subject to 20 nm Spacing Restrictions

Aircraft ID	Current spacing (distance between this aircraft and aircraft ahead of it)	Required spacing for this aircraft	Spacing achieved if this aircraft's provisional plan is implemented
DAL721*	30	0	NP
UAL104	15	5	0
CAL155	15	10	NP
AAL329*	35	0	NP
TWA463	-25	45	5
CAL621	50	15	NP
DAL891	30	5	NP
UAL333	10	15	NP
TWA734*	45	0	NP

Table 5. Spacing List for Center Airspace Subject to 20 nm Spacing Restrictions after AAL329's Provisional Plan made Active

Legend for Tables:
* indicates an aircraft is a "reference aircraft"
The red font indicates aircraft owned by sector
NP indicates no provisional plan exists for that aircraft
Required spacing = Spacing Restriction (i.e., 20 nm) + Required Spacing from row above – Current Spacing. If Required Spacing < 0 then set Required Spacing = 0.

3 Roles, Responsibilities, and Procedures

3.1 Sector Responsibility for Multi-sector Problems

The first step in the process of determining which sector is responsible for a multi-sector conflict and flow-rate constraint problem is to determine which aircraft should be maneuvered in a trajectory-oriented paradigm. The sector that has jurisdiction for (i.e., "owns") the aircraft to be maneuvered, by default, becomes the sector responsible for the problem resolution. The term "maneuver" is used throughout this paper to imply either an immediate action that results in a change to the active plan (the trajectory the aircraft would be expected to fly) or an action that may occur later in time, but is still a change to the active plan. The active plan contains information about speed (cruise, descent, climb), altitude (cruise, cleared), route, heading, and crossing restrictions.

3.1.1 Determine Aircraft to be Maneuvered

In the event that two aircraft are in conflict, regardless of the conflict type, the criteria for determining which aircraft should be maneuvered is based on a fundamental concept of trajectory-oriented strategic planning. This concept asserts that upstream maneuvers, if they are required to resolve a conflict, should also satisfy downstream flow-rate constraints and not create new conflicts. For a given conflict pair, there are six combinations possible for aircraft subject to flow-rate constraints:

1. Neither aircraft is subject to flow-rate constraints.

2. Only one of the aircraft is subject to flow-rate constraints and that aircraft is in conformance with the constraint.

3. Only one of the aircraft is subject to flow-rate constraints, but that aircraft is not in conformance.

4. Both aircraft are subject to flow-rate constraints and both are in conformance.

5. Both aircraft are subject to flow-rate constraints – one aircraft is in conformance, but the other aircraft is not in conformance.

6. Both aircraft are subject to flow-rate constraints and neither are in conformance.

The priority for maneuvering aircraft for these combinations, based on the trajectory-oriented concept, can be summarized as:

- **1st Priority** If an aircraft is subject to flow-rate constraints, but not in conformance with those constraints, maneuver that aircraft to bring it into conformance. There is a good possibility that this will resolve the conflict as well.

- **2nd Priority** If an aircraft is not subject to flow-rate constraints, maneuver that aircraft to resolve the conflict.

- **Lowest Priority** If an aircraft is subject to flow-rate constraints and in conformance with those constraints, maneuver that aircraft as a last choice because it most likely will require a second maneuver to put the aircraft back in conformance.

Using this approach, the controller often times will be able to solve two problems (i.e., a conflict and a metering violation) with a single maneuver. Table 6 uses the above priorities to identify which aircraft should be maneuvered for the conflict combinations.

		Aircraft A		
		Not subject to flow-rate restrictions	Subject to flow-rate restrictions and in conformance	Subject to flow-rate restrictions and not in conformance
Aircraft B	Not subject to flow-rate restrictions	Either	Aircraft B	Aircraft A
	Subject to flow-rate restrictions and in conformance	Aircraft A	Either	Aircraft A
	Subject to flow-rate restrictions and not in conformance	Aircraft B	Aircraft B	Either

Table 6. Criteria for Determining which Aircraft to Maneuver

In the event that two aircraft are in conflict and one of the following conditions exist (as represented by the "Either" boxes in Table 6):

1. Neither aircraft is subject to flow-rate constraints

2. Both aircraft are subject to flow-rate constraints and both are in conformance

3. Both aircraft are subject to flow-rate constraints and neither are in conformance

then the decision about which aircraft to be maneuvered depends on other conditions. Sector responsibility for the four conflict types in nominal situations is shown in Table 7. Only the Inter-sector conflict type results in significantly different responsibilities than exist in today's operations.

Conflict Type	Sector Responsibility
Intra-sector	As in today's operations, the sector where the conflict is predicted to occur is responsible for resolving the conflict.
Inter-sector	The responsibility for determining which sector will resolve the conflict is shared between the two sectors that have jurisdiction for the aircraft in the conflict pair.
External	Dependent on Table 9. In general, as in today's operations, the sector that has jurisdiction for both of the aircraft in the conflict pair is responsible for resolving the conflict.
External Intruder	As in today's operations, the sector where the conflict is predicted to occur is responsible for resolving the conflict.

Table 7. Sector Responsibility based on Conflict Type

For conflict pairs that are categorized by one of the three conditions above, the aircraft to be maneuvered can be determined by using conflict type as a tie breaker:

- For External Intruder, the sector where the point of conflict occurs should maneuver the aircraft that it owns (e.g., Aircraft A/ Sector 1 in Figure 1a).
- For Inter-sector conflicts, coordination between the sectors that own the aircraft is required to determine which aircraft should be maneuvered (Sectors 2 & 3 in Figure 1e)
- For Intra-sector and External conflict types, rules from current day procedures (e.g., if an aircraft will soon start its descent, then descend that aircraft early to resolve the conflict) and controller discretion will determine which aircraft should be maneuvered.

Table 8 uses the flow-rate restriction and conflict type logic to further clarify which aircraft in conflict should be maneuvered.

		Aircraft A								
		Intra-sector & External			External Intruder (Aircraft A in same sector as point of conflict, Aircraft B in upstream)			Inter-sector		
		1	2	3	1	2	3	1	2	3
Aircraft B	1	CDP	B	A	A	B	A	Coord	B	A
	2	A	CDP	A	A	A	A	A	Coord	A
	3	B	B	CDP	B	B	A	B	B	Coord

Table 8. Aircraft to be Maneuvered based on Conflict Type and Flow-rate Restriction

1 – Aircraft not subject to flow-rate restrictions
2 – Aircraft subject to flow-rate restrictions and in conformance
3 – Aircraft subject to flow-rate restrictions and not in conformance
A – Aircraft A
B – Aircraft B
CDP – Current day procedures and controller discretion determine which aircraft to maneuver
Coord – Coordination required between the two sectors that own aircraft

Of 27 possible outcomes, 21 of them are deterministic and 24 of them do not require coordination between sectors for resolution. For the cases where coordination or current day procedures are needed to determine which aircraft to maneuver, controller discretion may be aided by information displayed in the metering lists and provisional plans.

The last condition that can determine which aircraft to maneuver is based on the location of the aircraft relative to both the conflict location and the sector boundary. If an aircraft is near the sector boundary, determining whether the upstream or downstream controller resolves the conflict is dependent on how close the aircraft is to the sector boundary. At the same time, by alerting upstream and downstream controllers to conflicts even if they are not responsible for their resolution increases their situational awareness.

Existing procedures are not always efficient when applied to trajectory orientation. In today's operations, the upstream controller is always responsible for External conflicts. The downstream controller might be involved in the resolution, but the upstream controller is responsible for initiating any required coordination. However, with the long conflict detection time horizon (15-20 min) provided by EDA, if the aircraft is near the sector boundary, it is more efficient for the downstream controller to take responsibility for the resolution. Table 9 uses Time to Sector Boundary and Time to Conflict to further clarify which sector is responsible.

Intra-sector Conflict		
Time to Sector Boundary (min)	Time to Conflict (min)	
	> 0	
> 0	Downstream	
Inter-sector Conflict		
Time to Sector Boundary	Time to Conflict	
	> 0	
0 – 3	Downstream	
> 3	Upstream	
External Conflict		
Time to Sector Boundary for the aircraft nearer to boundary	Time to Conflict	
	0 – 10	> 10
0 – 3	Upstream	Downstream
> 3	Upstream	Upstream
External Intruder Conflict Case 1 (For case in Table 8 where Aircraft A should be maneuvered)		
Time to Sector Boundary for Aircraft A	Time to Conflict	
	> 0	
> 0	Downstream	
External Intruder Conflict Case 2 (For case in Table 8 where Aircraft B should be maneuvered)		
Time to Sector Boundary for Aircraft B	Time to Conflict	
	> 0	
0 – 3	Downstream	
> 3	Upstream	

Table 9. Sector Responsibility by Conflict Type for Aircraft Transitioning Sectors

The information contained in Tables 8 & 9 summarizes the decision process and should be included in the active conflict detection list as described in Section 2.2.1. As mentioned earlier, the sector that owns the aircraft to be maneuvered has responsibility for resolving the conflict (as described in Table 8). The exception to this is when the handoff process has been or is soon to be initiated. In this case, sometimes it is more efficient for the downstream to take responsibility. Table 9 addresses those instances.

3.2 Sector Responsibility for Metering Conformance

In the event that a metered aircraft is not in conflict with any other aircraft, the responsibility for meeting the STA is placed upon the sector that currently has jurisdiction for the aircraft. The sector team should maneuver the aircraft as needed to meet the STA before the aircraft leaves the sector.

3.3 Sector Responsibility for Metering Spacing

In the event that an aircraft subject to spacing constraints is not in conflict with any other aircraft, the responsibility for meeting the spacing restriction is placed upon the sector that currently has jurisdiction for the aircraft. The sector team should maneuver the aircraft as needed to meet the STA before the aircraft leaves the sector.

3.3 Sector Position Responsibility

This section describes two approaches to delegating responsibility to the R-side or D-side positions within the sector team. Due to concerns about individual controller preferences and styles, the author was not able to down-select to a single approach. Both approaches have pros and cons that may not be compatible with different sector teams. In fact, in both cases, the approaches described should be viewed as a guideline rather than a definitive rule set. *It is strongly recommended that these guidelines be an aspect of the controller evaluations of EDA.*

In both approaches, the R-side solves all stand-alone flow-rate conformance problems and, at his/her discretion, any conflict that involves flow-rate conformance. The reason for this is that an R-side's plan for spacing or metering multiple aircraft is dependent on a series of actions occurring in the proper sequence. This type of planning would be very difficult to share with a D-side. Without the knowledge of the R-side's intentions, it is very likely that attempts by the D-side to implement flow-rate conformance for random aircraft would interfere with the R-side's plan.

The first approach has the D-side controller resolving strategic conflicts and the R-side controller performing tactical conflicts. Strategic in this case refers to longer time horizons to the conflict whereas tactical refers to shorter time horizons. The sector position responsibilities for conflicts are shown in Table 10 and are a function of the conflict type, Time to Conflict, Time to Sector Boundary. In the cases that the Time to Sector Boundary is less than 3 minutes, the handoff process has either begun or is soon to begin. This means that the upstream controller can not maneuver the aircraft without coordinating with downstream controller first.

The second approach (Table 11)has the D-side controller resolving external conflicts (i.e., External, Inter-sector, and some External Intruder conflicts). The R-side controller resolves all internal conflicts (i.e., Intra-sector and some External Intruder and External conflicts). In addition, the R-side resolves External conflicts if the Time to Sector Boundary is less than 3 minutes because this case will most likely result in coordination during the handoff to the downstream sector.

It is important to note that the position responsibility presented here is strongly dependent on the sector notification of conflict detection as discussed in 2.2. If the sector notification logic were to change, the position responsibility would need to be redefined.

<table>
<tr><th colspan="7">Intra-sector Conflict</th></tr>
<tr><td rowspan="2">Time to Sector Boundary (min)</td><td colspan="6">Time to Conflict (min)</td></tr>
<tr><td colspan="3">0 – 10</td><td colspan="3">> 10</td></tr>
<tr><td>> 0</td><td colspan="3">R-side</td><td colspan="3">D-side</td></tr>
<tr><th colspan="7">Inter-sector Conflict</th></tr>
<tr><td rowspan="2">Time to Sector Boundary</td><td colspan="6">Time to Conflict</td></tr>
<tr><td colspan="2">0 – 3</td><td colspan="2">3 – 10</td><td colspan="2">> 10</td></tr>
<tr><td>0 – 3</td><td colspan="2">Downstream</td><td colspan="2">Downstream</td><td colspan="2">Downstream</td></tr>
<tr><td>> 3</td><td colspan="2">NA</td><td colspan="2">R-side</td><td colspan="2">D-side</td></tr>
<tr><th colspan="7">External Conflict</th></tr>
<tr><td rowspan="2">Time to Sector Boundary for aircraft nearer boundary</td><td colspan="6">Time to Conflict</td></tr>
<tr><td colspan="3">0 – 10</td><td colspan="3">> 10</td></tr>
<tr><td>0 – 3</td><td colspan="3">R-side</td><td colspan="3">Downstream</td></tr>
<tr><td>> 3</td><td colspan="3">R-side</td><td colspan="3">D-side</td></tr>
<tr><th colspan="7">External Intruder Conflict Case 1
(For case in Table 8 where Aircraft A should be maneuvered)</th></tr>
<tr><td rowspan="2">Time to Sector Boundary for Aircraft A</td><td colspan="6">Time to Conflict</td></tr>
<tr><td colspan="3">0 – 10</td><td colspan="3">> 10</td></tr>
<tr><td>> 0</td><td colspan="3">R-side</td><td colspan="3">D-side</td></tr>
<tr><th colspan="7">External Intruder Conflict Case 2
(For case in Table 8 where Aircraft B should be maneuvered)</th></tr>
<tr><td rowspan="2">Time to Sector Boundary for Aircraft B</td><td colspan="6">Time to Conflict</td></tr>
<tr><td colspan="3">0 – 10</td><td colspan="3">> 10</td></tr>
<tr><td>0 – 3</td><td colspan="3">Downstream</td><td colspan="3">Downstream</td></tr>
<tr><td>> 3</td><td colspan="3">R-side</td><td colspan="3">D-side</td></tr>
</table>

Table 10. Sector Team Responsibility by Conflict Type

<table>
<tr><th colspan="3">Intra-sector Conflict</th></tr>
<tr><td rowspan="2">Time to Sector Boundary (min)</td><td colspan="2">Time to Conflict (min)</td></tr>
<tr><td colspan="2">> 0</td></tr>
<tr><td>NA</td><td colspan="2">R-side</td></tr>
<tr><th colspan="3">Inter-sector Conflict</th></tr>
<tr><td rowspan="2">Time to Sector Boundary</td><td colspan="2">Time to Conflict</td></tr>
<tr><td>0 – 3</td><td>> 3</td></tr>
<tr><td>0 – 3</td><td>Downstream</td><td>Downstream</td></tr>
<tr><td>> 3</td><td>NA</td><td>D-side</td></tr>
<tr><th colspan="3">External Conflict</th></tr>
<tr><td rowspan="2">Time to Sector Boundary for aircraft in pair nearer to boundary</td><td colspan="2">Time to Conflict</td></tr>
<tr><td>0 – 10</td><td>> 10</td></tr>
<tr><td>0 – 3</td><td>R-side</td><td>Downstream</td></tr>
<tr><td>> 3</td><td>D-side</td><td>D-side</td></tr>
<tr><th colspan="3">External Intruder Conflict Case 1
(For case in Table 8 where Aircraft A should be maneuvered)</th></tr>
<tr><td rowspan="2">Time to Sector Boundary for Aircraft A</td><td colspan="2">Time to Conflict</td></tr>
<tr><td colspan="2">> 0</td></tr>
<tr><td>> 0</td><td colspan="2">R-side</td></tr>
<tr><th colspan="3">External Intruder Conflict Case 2
(For case in Table 8 where Aircraft B should be maneuvered)</th></tr>
<tr><td rowspan="2">Time to Sector Boundary for Aircraft B</td><td colspan="2">Time to Conflict</td></tr>
<tr><td colspan="2">> 0</td></tr>
<tr><td>0 – 3</td><td colspan="2">Downstream</td></tr>
<tr><td>> 3</td><td colspan="2">D-side</td></tr>
</table>

Table 11. Sector Team Responsibility by Conflict Type (Alternate Approach)

4 References

1. Green, S., "NASA AATT Milestone 5.10, En Route Descent Advisor Concept Definition," NASA AATT Project Office, NASA Ames Research Center, Moffett Field, CA 94035, December, 1999.

2. “En Route Descent Advisor (EDA) System Specification,” RTO-45 NAS2-98005, NASA AATT Project Office, NASA Ames Research Center, Moffett Field, CA 94035, December, 2000.

3. “RTO-34B Final Report,” NASA AATT Project Office, NASA Ames Research Center, Moffett Field, CA 94035, May, 2000.